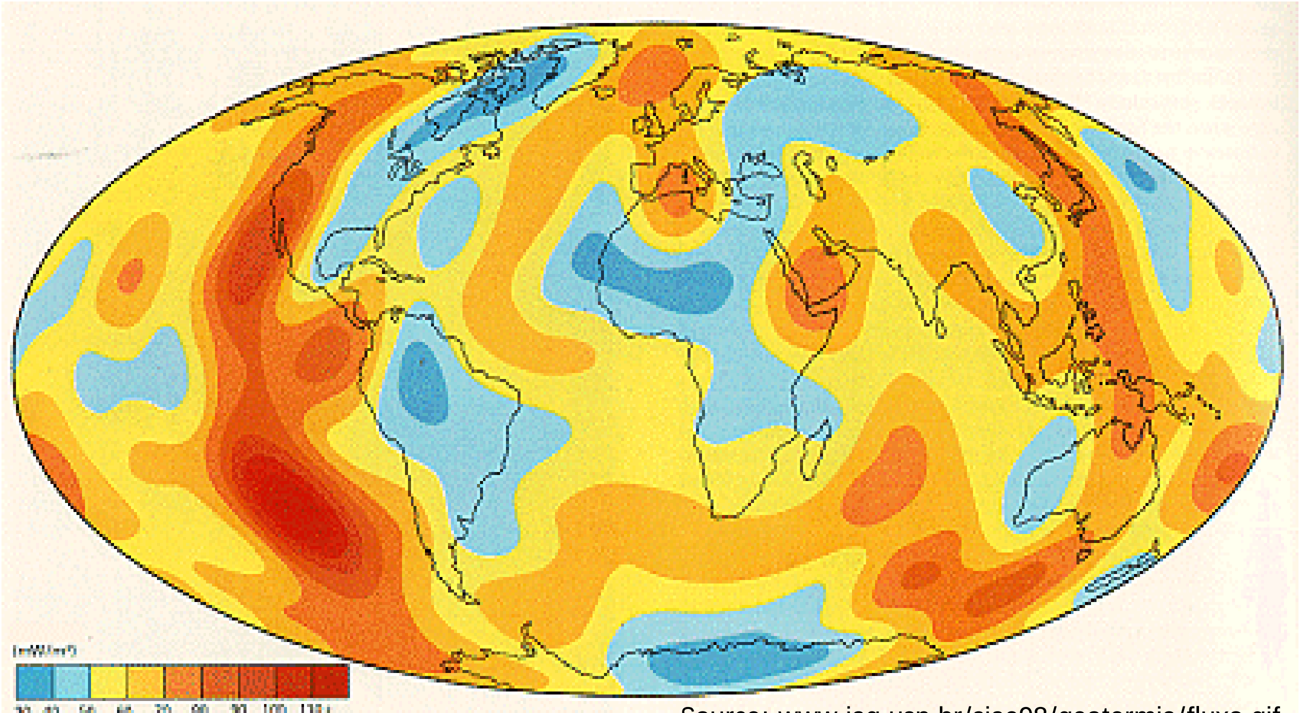
LOWBIN PROJECT

2nd Low-Bin Meeting



Source: www.iag.usp.br/siae98/geotermia/fluxo.gif

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WORK TEAM

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LOWBIN PROJECT

MAIN ACTIVITIES OF ESTSETUBAL IN LOWBIN PROJECT:

- **WP#2**
  - **Evaluation of working fluids**
    - **Main working fluids (bibliography)**
    - **Computer programs (Cycle-Tempo)**
  - **Technology assessment of heat exchangers (assistance)**
- **WP#3**
  - **Pre-prototype development**
  - **Laboratory measurements of prototype energy (assistance)**
- **WP#5**
  - **Monitoring and analysing geothermal energy parameters, ...**
  - **Technology validation report**
- **WP#6**
  - **Presentations in conferences and papers in scientific journals**

WORKING FLUIDS

Organic Fluids

- Higher turbine efficiencies due to higher mass flow
- Low maintenance operation
- Good part load behaviour

WORKING FLUIDS – Characteristics of the "ideal" working fluid

- **High specific heat for enlarging heat capacity**
- **Fluid's critical point (pressure and temperature) should be above the engine's operating temperature**
- **High critical temperature for safe elevation of evaporating temperature**
- **Required operating pressure should not put danger of explosion or rupture**
- **Fluid's pressure inside the condenser should be above ambient air pressure (prevent air inflow)**
- **Fluid volume in its gaseous state should be small enough to avoid the need for costly, over-sized turbines, boilers, and condensers.**

WP#2 Evaluation of working fluids

WORKING FLUIDS - Additional requirements for ORC applications

- Low costs of installation, equipment, maintenance, and operation
- The gas should not require superheating
- Should have a high molecular weight and self-lubricity for the smooth rotation of the turbine and the pump
- At ambient air conditions (pressure and temperature) need to be in a liquid state
- Low latent heat - Capacity to absorb and reject heat easily, lowering heat loss
- High chemical and thermal stability - Maintain its stability at the highest temperatures, non-flammable, non-corrosive and non-toxic
- Lower boiling point and higher vapor pressure than water

MAIN WORKING FLUIDS (BIBLIOGRAPHY)

FLUID		CRITICAL PARAMETERS PRESSURE (bar)	TEMPERATURE (°C)
propane/ethane	0.9 propane/0.1 ethane		90.7
	0.8 propane/0.2 ethane		84.6
	0.7 propane/0.3 ethane		78.4
	0.6 propane/0.4 ethane		72.1
	0.5 propane/0.5 ethane		65.7
propylene		46.1	92.4
R227ae		29.5	101.9
RC318		27.8	115.2
R236fa		32.0	124.92
Isobutane		36.3	134.7
R245fa		36.4	154.05

“Power production from a moderate-temperature geothermal resource”

Joost J. Brasz, Bruce P. Biederman, Gwen Holdmann; USA (2005)

Władysław Nowak and Aleksandra Borsukiewicz; Szczecin University of Technology, Poland (2005)

WP#2 Evaluation of working fluids

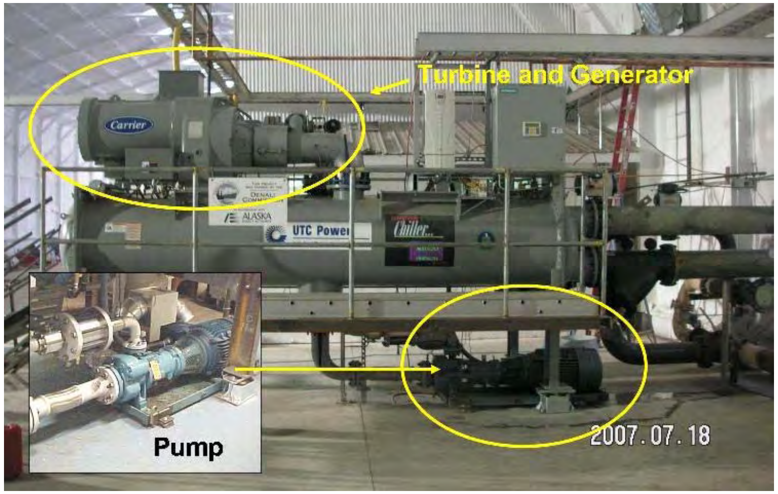
MAIN WORKING FLUIDS (BIBLIOGRAPHY)

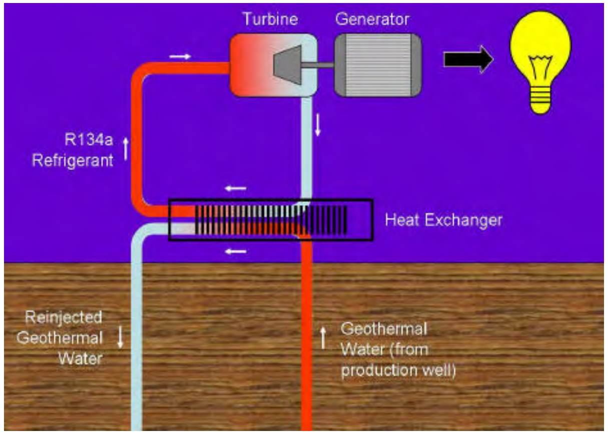
	CRITICAL PARAMETERS	
FLUID	**PRESSURE (bar)**	**TEMPERATURE (°C)**
R134a	40.7	101.2

- **"Research on generation of electricity from the geothermal resources in Simav region, Turkey"; Ramazan Köse; University of Dumlupinar (2004)**

Hot Source (Low) Temperature - 74°C

Electric Capacity - 400kWe





Source: http://www.yourownpower.com/Power/

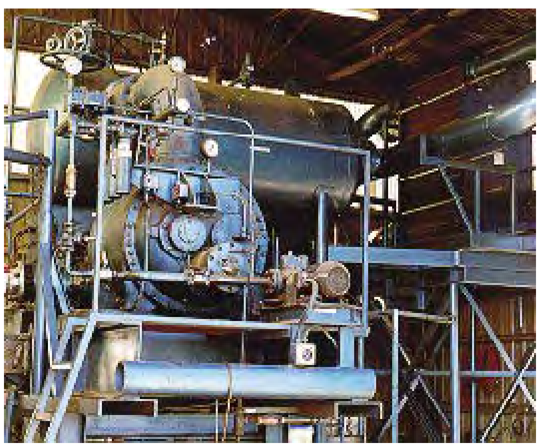
MAIN WORKING FLUIDS (BIBLIOGRAPHY)

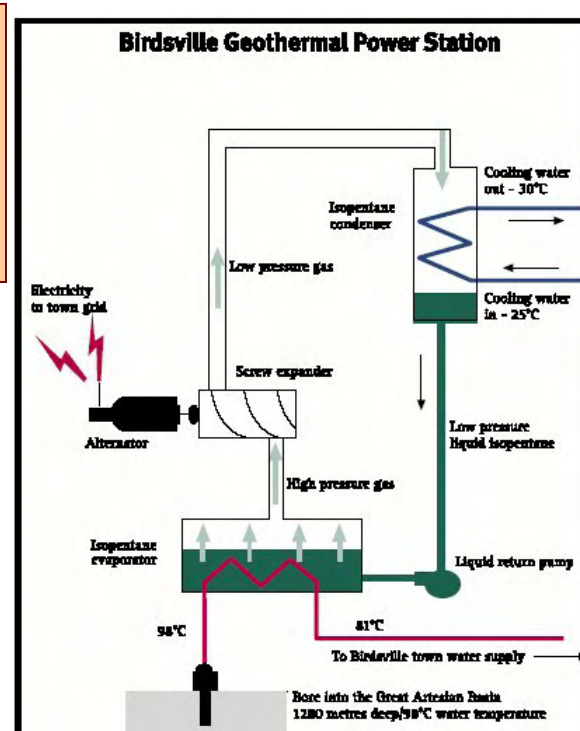
	CRITICAL PARAMETERS	
FLUID	PRESSURE (bar)	TEMPERATURE (°C)
isopentane	33.7	187.4

Used in Birdsville geothermal power plant in Queensland, Australia (2005):

Hot Source (Low) Temperature - 98°C

Electric Capacity - 120kWe





Source: http://www.epa.qld.gov.au/publications/p00834aa.pdf/Birdsville_geothermal_power_station.pdf

WP#2 Evaluation of working fluids

MAIN WORKING FLUIDS (BIBLIOGRAPHY)

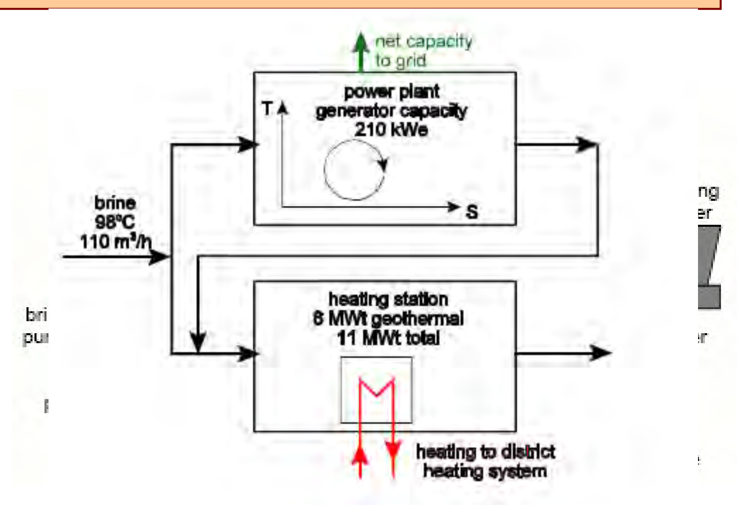
	CRITICAL PARAMETERS	
FLUID	PRESSURE (bar)	TEMPERATURE (°C)
n-perfluorpentane (C_5H_{12})	20.6	146.8

Used in combined heat and power plant, Neustadt-Glewe, Germany (2003) :

Hot Source (Low) Temperature - 98°C

Heating Capacity - 11 MWth

Electric Capacity - 210kWe



Source: http://geoheat.oit.edu/bulletin/bull26-2/art8.pdf

WP#2 Evaluation of working fluids

MAIN WORKING FLUIDS (BIBLIOGRAPHY)

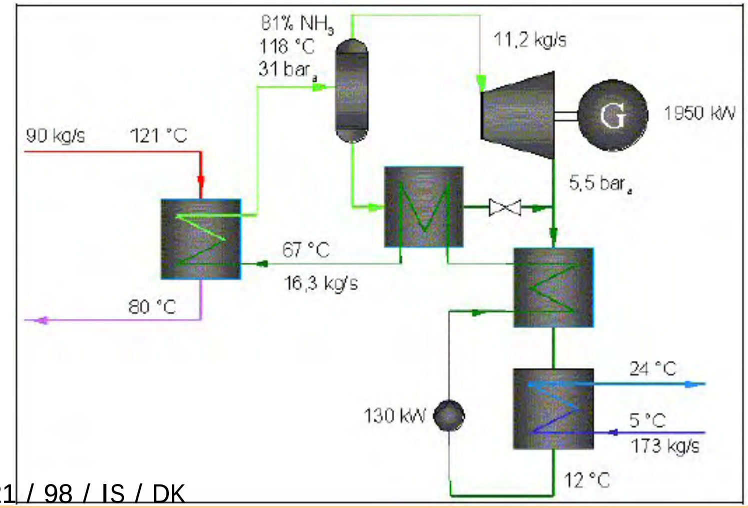
	CRITICAL PARAMETERS	
FLUID	PRESSURE (bar)	TEMPERATURE (°C)
Ammonia (NH_3) (Kalina)	112.8	132.35

Used in combined heat and power plant, Húsavík , Iceland (2000) :

Hot Source (Low) Temperature - 121°C

Heating Capacity - 40 MWth

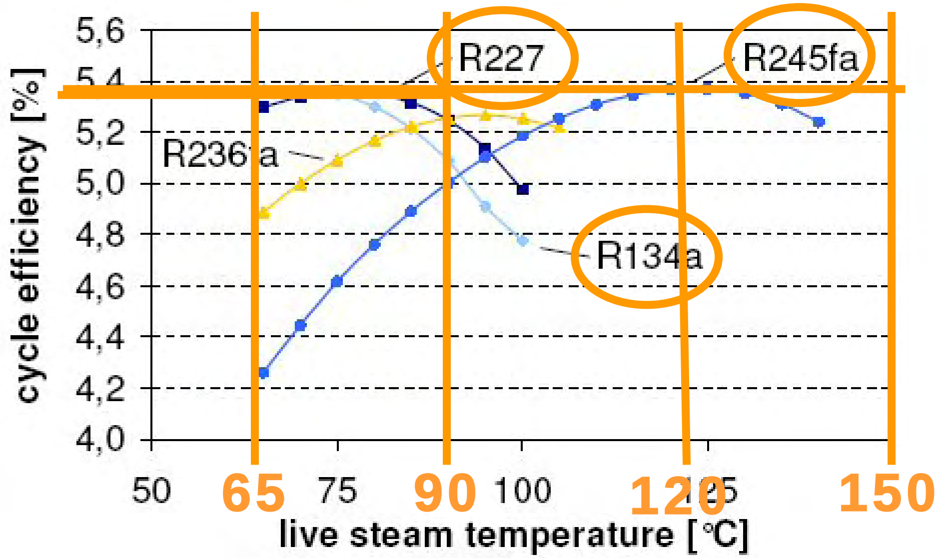
Electric Capacity – 2MWe



Source: Húsavík Energy, Multiple use of geothermal energy, Thermie project nr. GE 321 / 98 / IS / DK

WORKING FLUIDS

According to "The Organic Rankine Cycle – Power Production from Low Temperature Heat", Hartmut Spliethoff , Andreas Schuster (Technische Universität München – 2006)



- **For prototype to generate electricity from low temperature geothermal resource (65-90°C)**

- **For prototype to cogeneration of heat and power (120-150ºC)**

WP#2 Evaluation of working fluids

COMPUTER PROGRAMS RESEARCH

- **To study different working fluids behaviour in an organic Rankin cycle to:**
  - **help choosing the best working fluid**

- **The program should:**
  - **Allow to model with a great number of different working fluids**
  - **Allow the user to define different system components and cycle configuration**

CYCLE-TEMPO COMPUTER PROGRAM

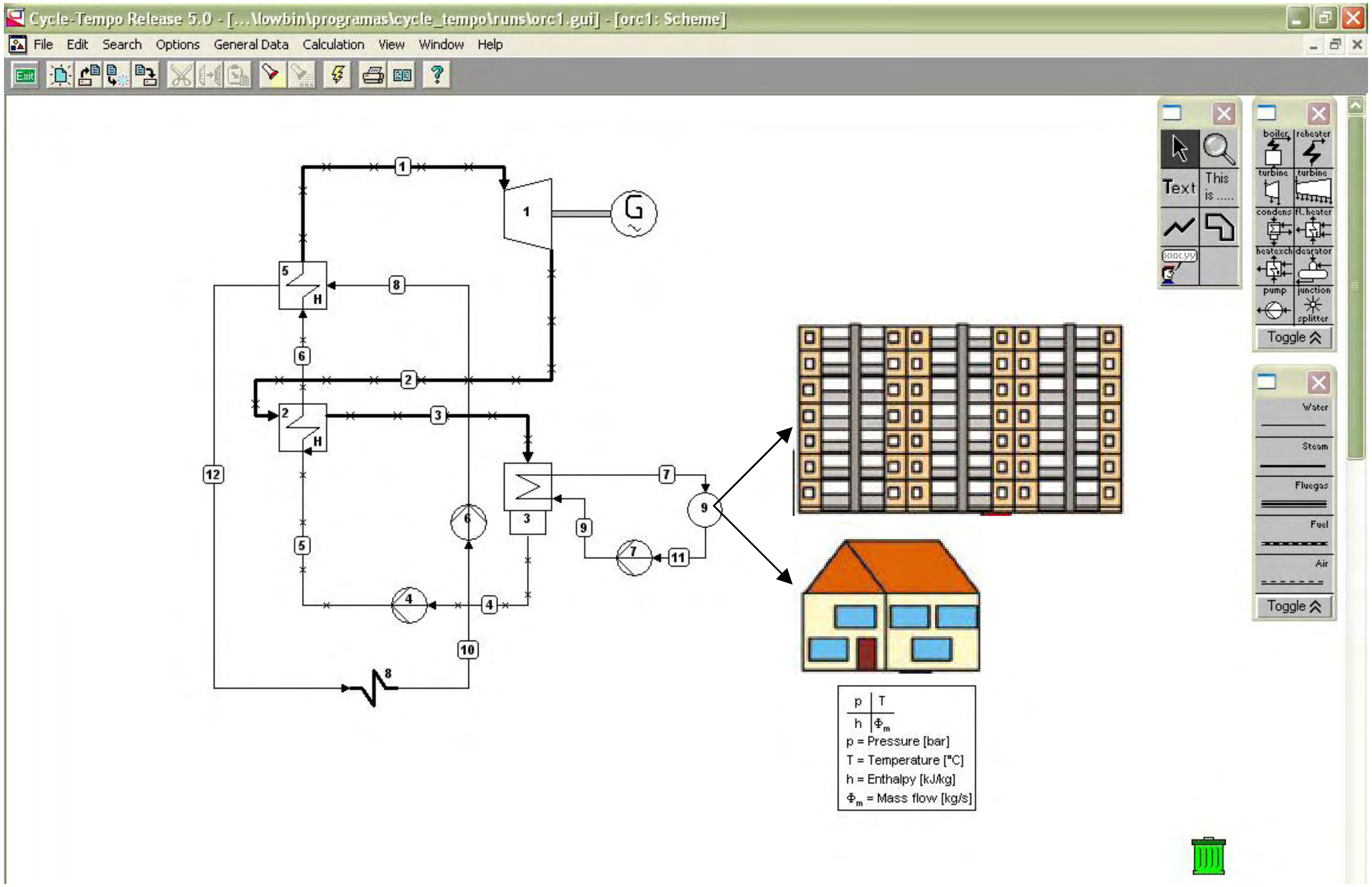
- Developed by Delft University of Technology (TUDelft) and Institute of Environmental Sciences (TNO), Netherlands
- Tool for thermodynamic analysis and optimization of energy systems by calculating all relevant mass and energy flows in the system
- The number and type of components and sub-systems, and the way in which they are connected are defined by the user
- Fully graphical program
- System configuration can be assembled as a Process Flow Diagram (PFD)
- Capability of performing the exergy analysis of the system (insight into the exergy flows and losses in sub-systems, looking for the optimal system configuration)

CYCLE-TEMPO COMPUTER PROGRAM

- **Applications:**
  - steam turbine cycles
  - gas turbine cycles
  - combined cycle plants
  - combustion and gasification systems
  - heat transfer systems
  - fuel cell systems (with low temperature as well as high temperature fuel cells)
  - organic Rankine cycles (ORC)
  - refrigeration systems (compression and absorption cycles)
  - heat pumps

WP#2 Evaluation of working fluids

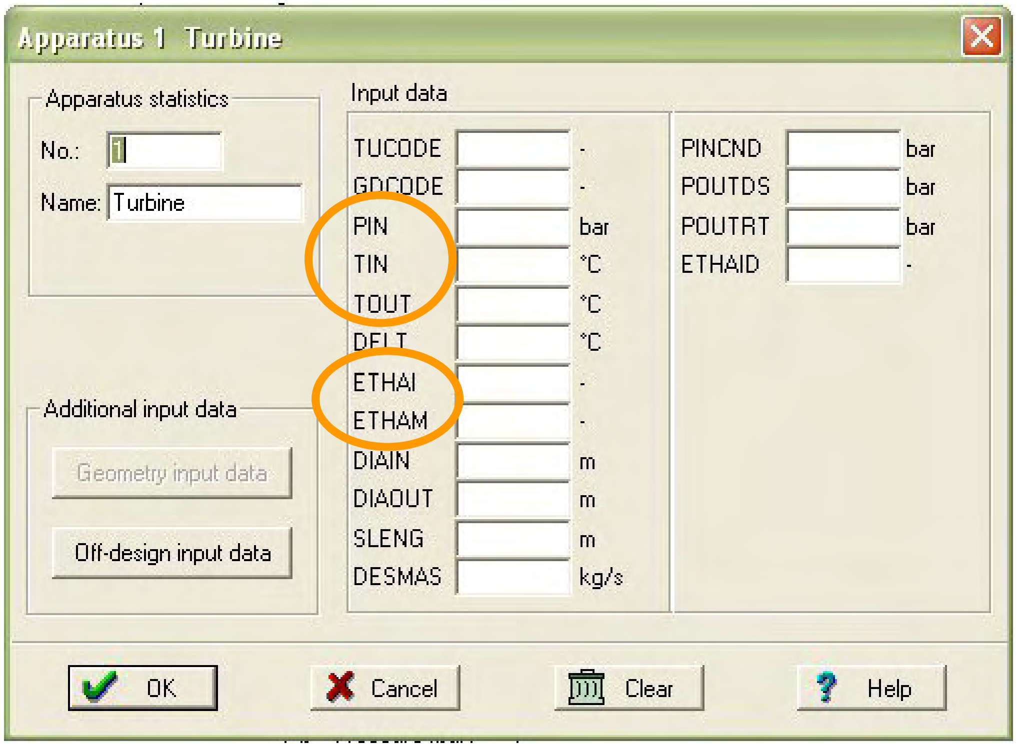
CYCLE-TEMPO COMPUTER PROGRAM – Drawing the cycle



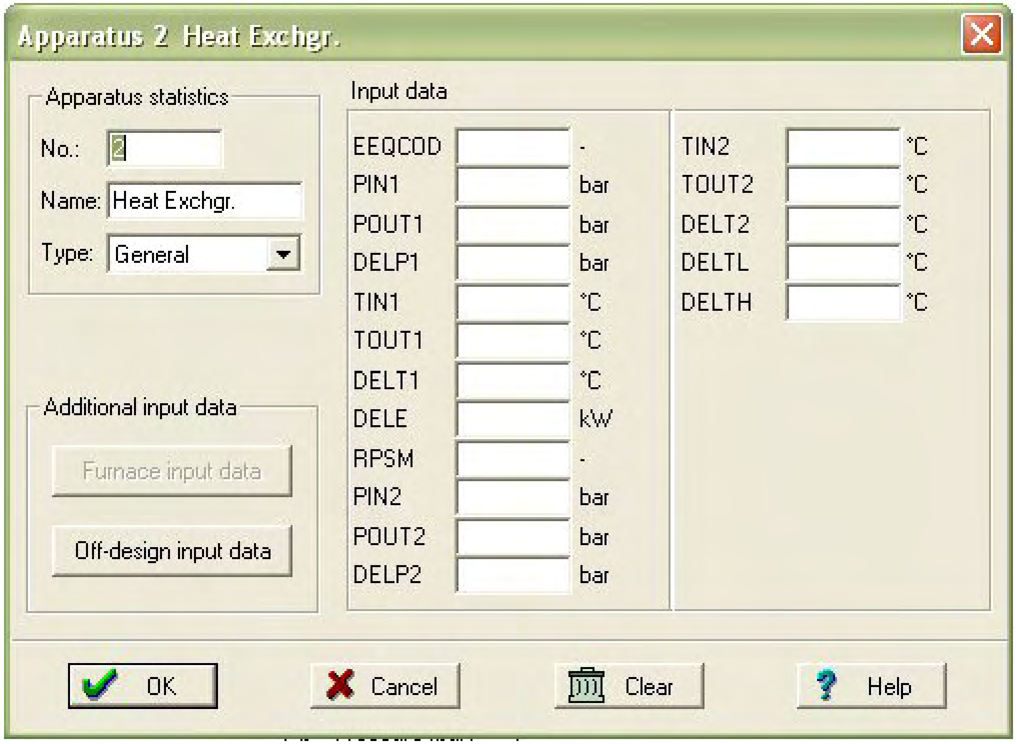
- For prototype to generate electricity from low temperature geothermal
- For prototype to cogeneration of heat and power (120-150ºC)

CYCLE-TEMPO COMPUTER PROGRAM – Input (turbine)

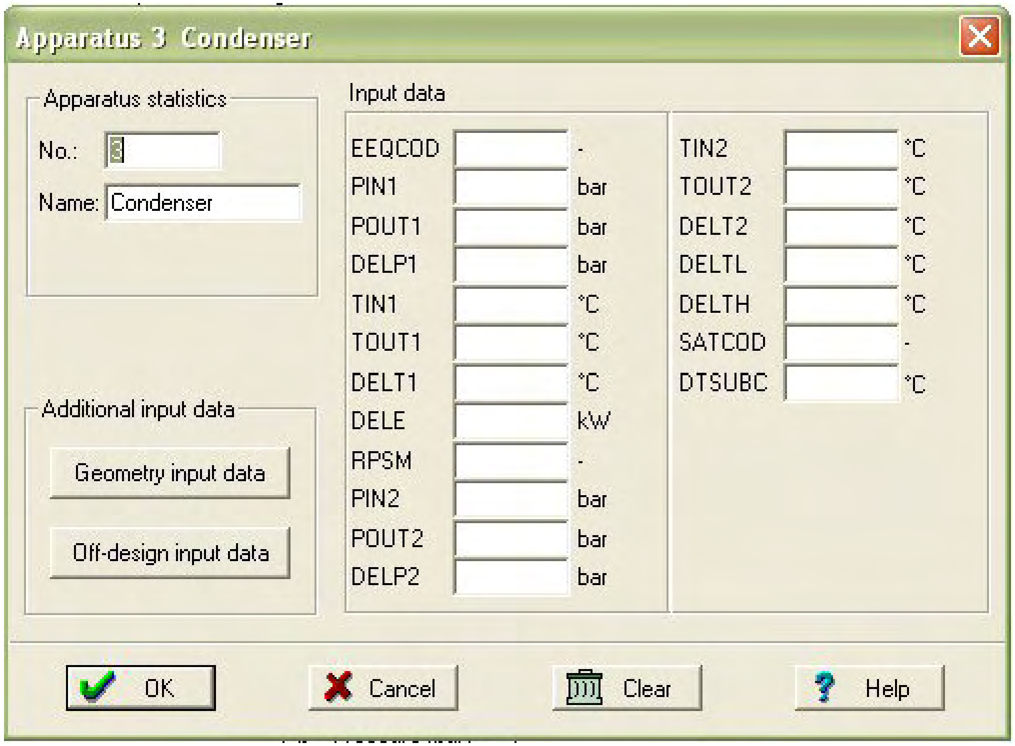
- Data input is made by filling property dialog boxes



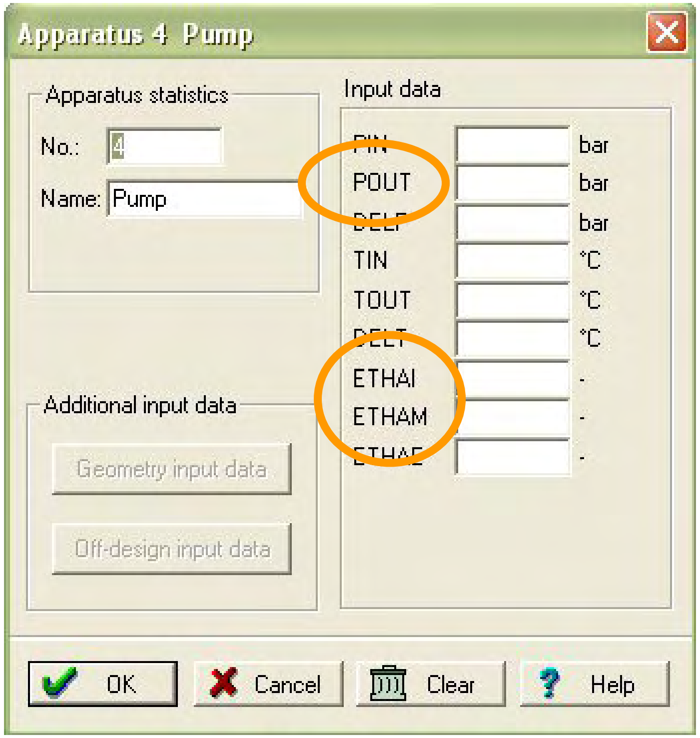
CYCLE-TEMPO COMPUTER PROGRAM – Input (heat exchanger)



CYCLE-TEMPO COMPUTER PROGRAM – Input (condenser)

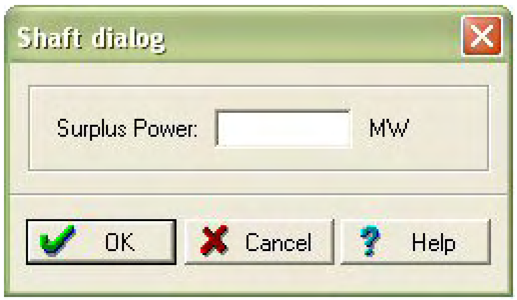


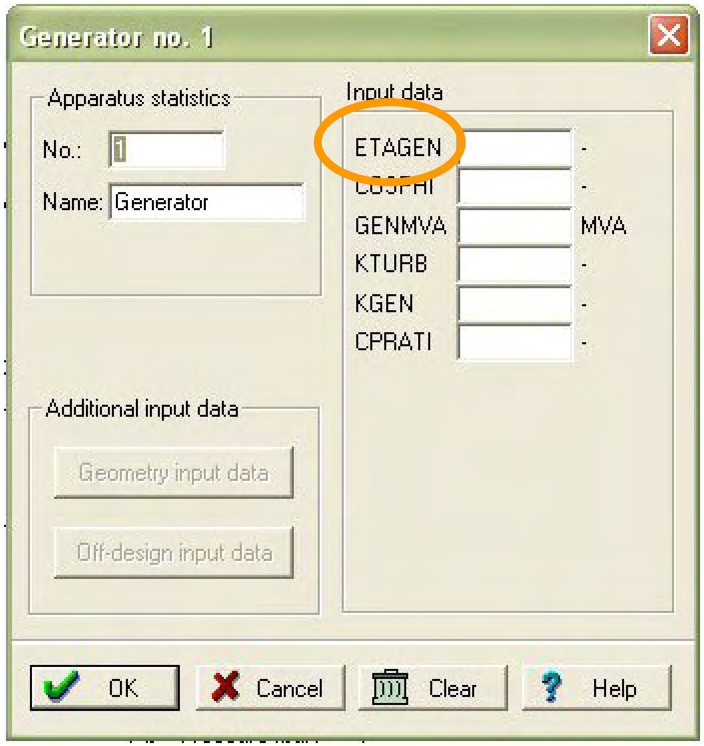
CYCLE-TEMPO COMPUTER PROGRAM – Input (pump)



WP#2 Evaluation of working fluids

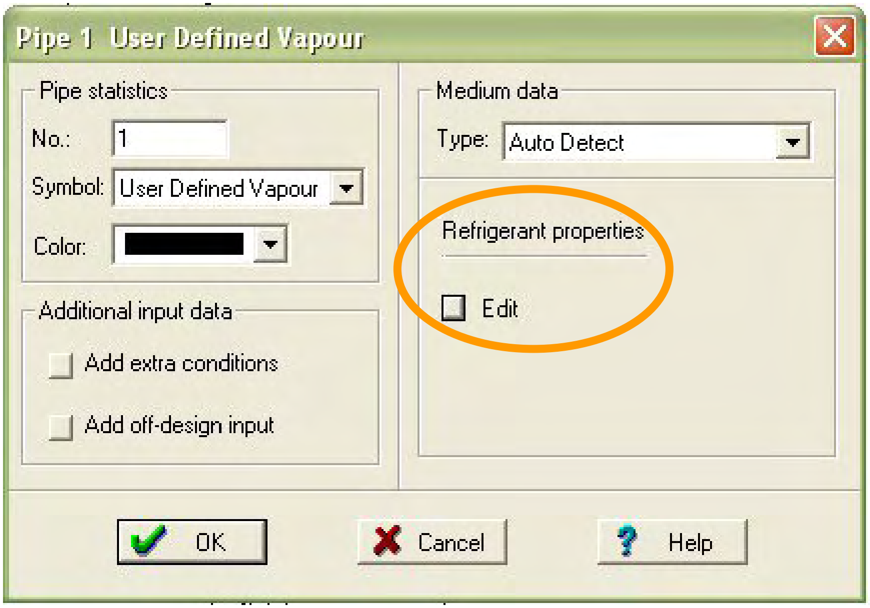
CYCLE-TEMPO COMPUTER PROGRAM – Input (shaft and generator)

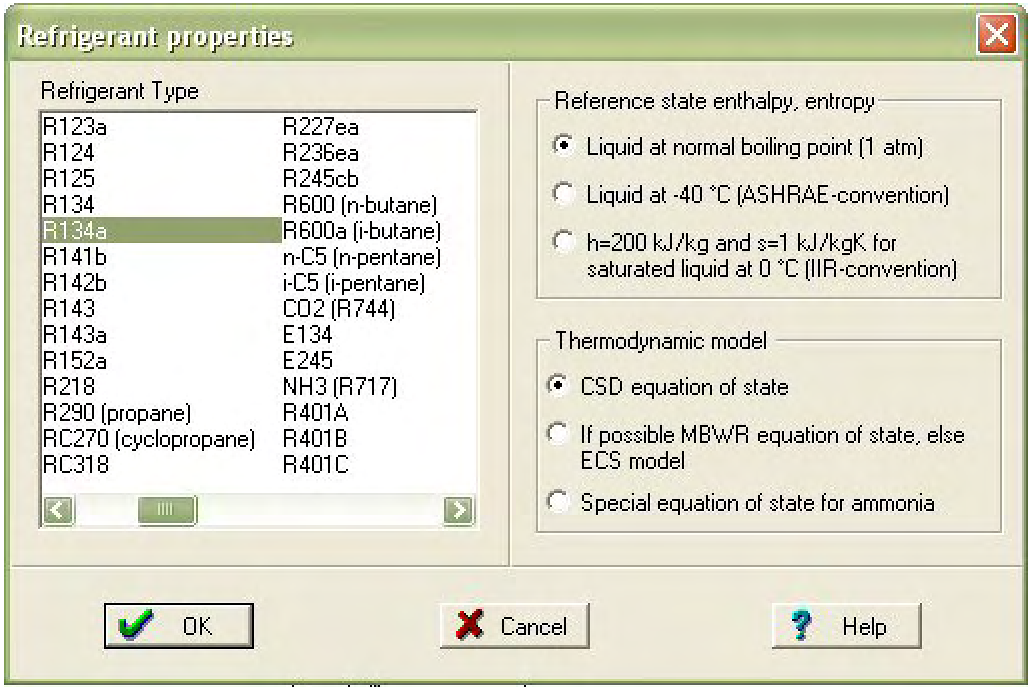




CYCLE-TEMPO COMPUTER PROGRAM – Input (pipe and fluid)

REFPROP library





WP#2 Evaluation of working fluids

CYCLE-TEMPO COMPUTER PROGRAM – Input (REFPROP)

- **Developed and maintained by the National Institute of Standard and Technologies**
- **Included fluids and mixtures:**
  - The HFCs R23, R32, R41, R125, **R134a**, R143a, R152a, **R227ea**, R236ea, **R236fa**, R245ca, and **R245fa**
  - The HCFCs R22, R123, R124, R141b, and R142b
  - The traditional CFCs R11, R12, R13, R113, R114, and R115
  - The fluorocarbons R14, R116, R218, and **RC318**
  - Ammonia, carbon dioxide, isobutane, and **propylene**
  - The main air constituents nitrogen, oxygen, and argon
  - Methane, **ethane**, **propane**, butane, and **isobutane**
  - Water (as a pure fluid, or mixed with ammonia)
  - 35 predefined mixtures (such as R407C, R410A, and Air)
  - the user may define and store others

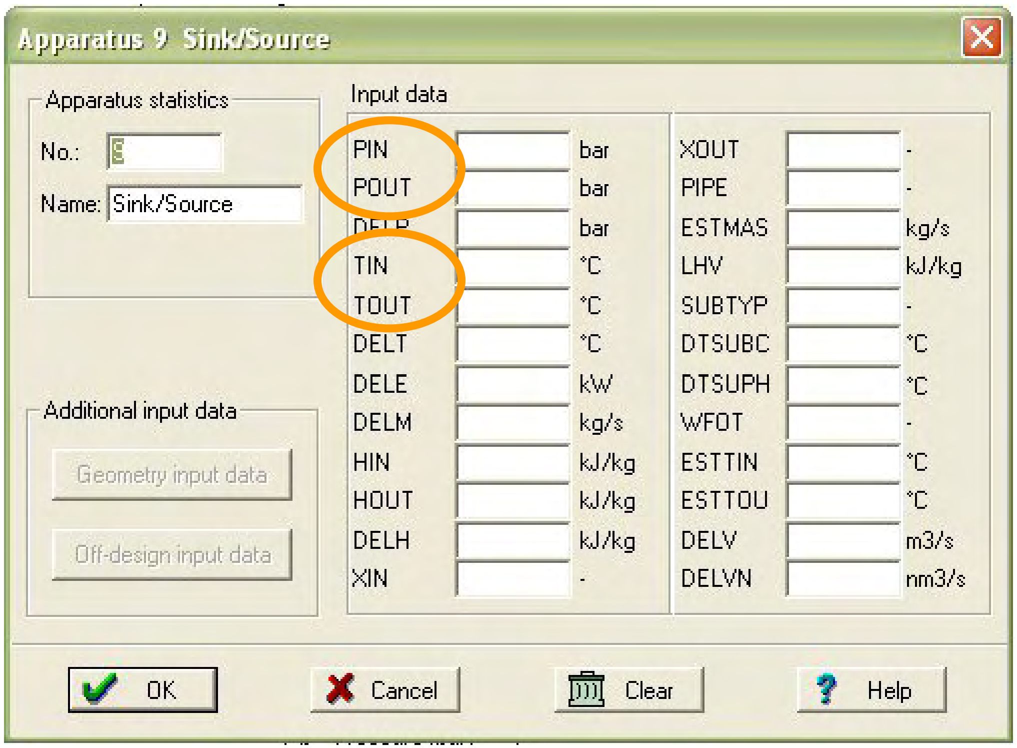
CYCLE-TEMPO COMPUTER PROGRAM – Input (REFPROP)

- **Available properties:**

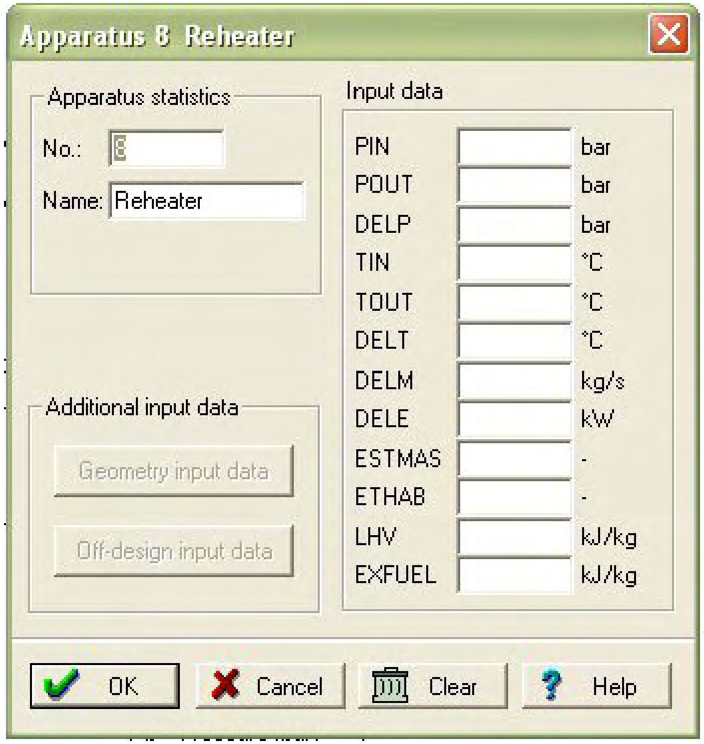
Temperature, **Pressure**, **Density**, Energy, **Enthalpy**, **Entropy**, Cv, Cp, Sound Speed, Compressibility Factor, Joule Thompson Coefficient, Quality, 2nd Virial Coefficient, 3rd Virial Coefficient, Helmholtz Energy, Gibbs Energy, **Heat of Vaporization**, Fugacity, Fugacity Coefficient, K value, **Molar Mass**, Thermal Conductivity, **Viscosity**, Kinematic Viscosity, Thermal Diffusivity, Prandtl Number, Surface Tension, Isothermal Compressibility, **Volume Expansivity**, Isentropic Coefficient, Adiabatic Compressibility, **Specific Heat Input**, Exergy, dp/dr, d2p/dr2, dp/dT, dr/dT, dr/dp

WP#2 Evaluation of working fluids

CYCLE-TEMPO COMPUTER PROGRAM – Input (cold source)

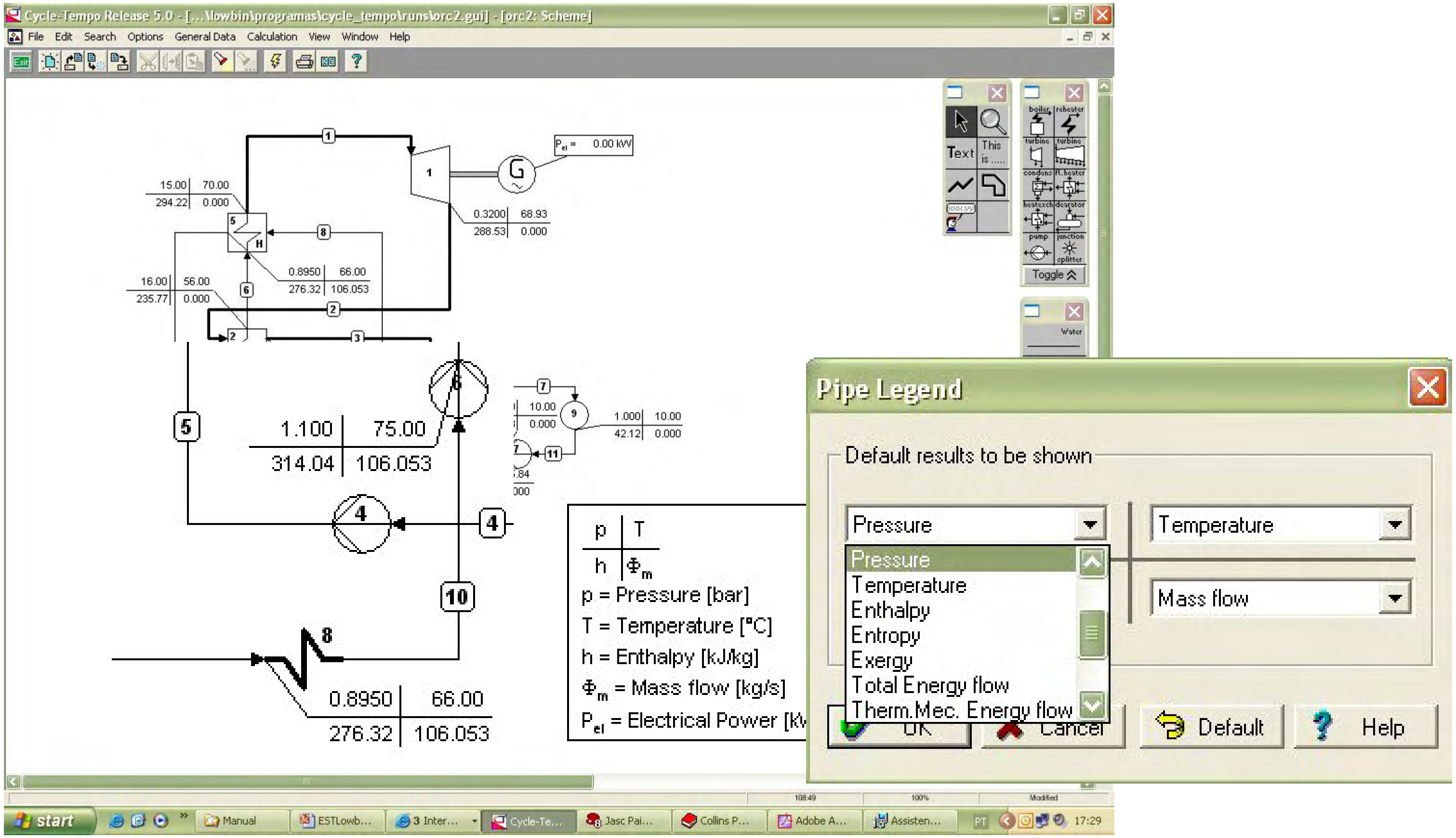


CYCLE-TEMPO COMPUTER PROGRAM – Input (hot source)



CYCLE-TEMPO COMPUTER PROGRAM – Results in the Diagram

- Results are available as well ordered charts, plots and tables



CYCLE-TEMPO COMPUTER PROGRAM – Results in Tables

Name of table	Condition for generation
System	...bsorbed > 0
Energy	
Compo...	...ompositions
Motors ...	...or
Heat ex...	...iters (type
	...arators
	(type 22) > 0

Setup table with calculation results

Table name: Table 12

1 6
2 7
3 8
4 9

Add->

Delete

Help

ex1: System efficiencies

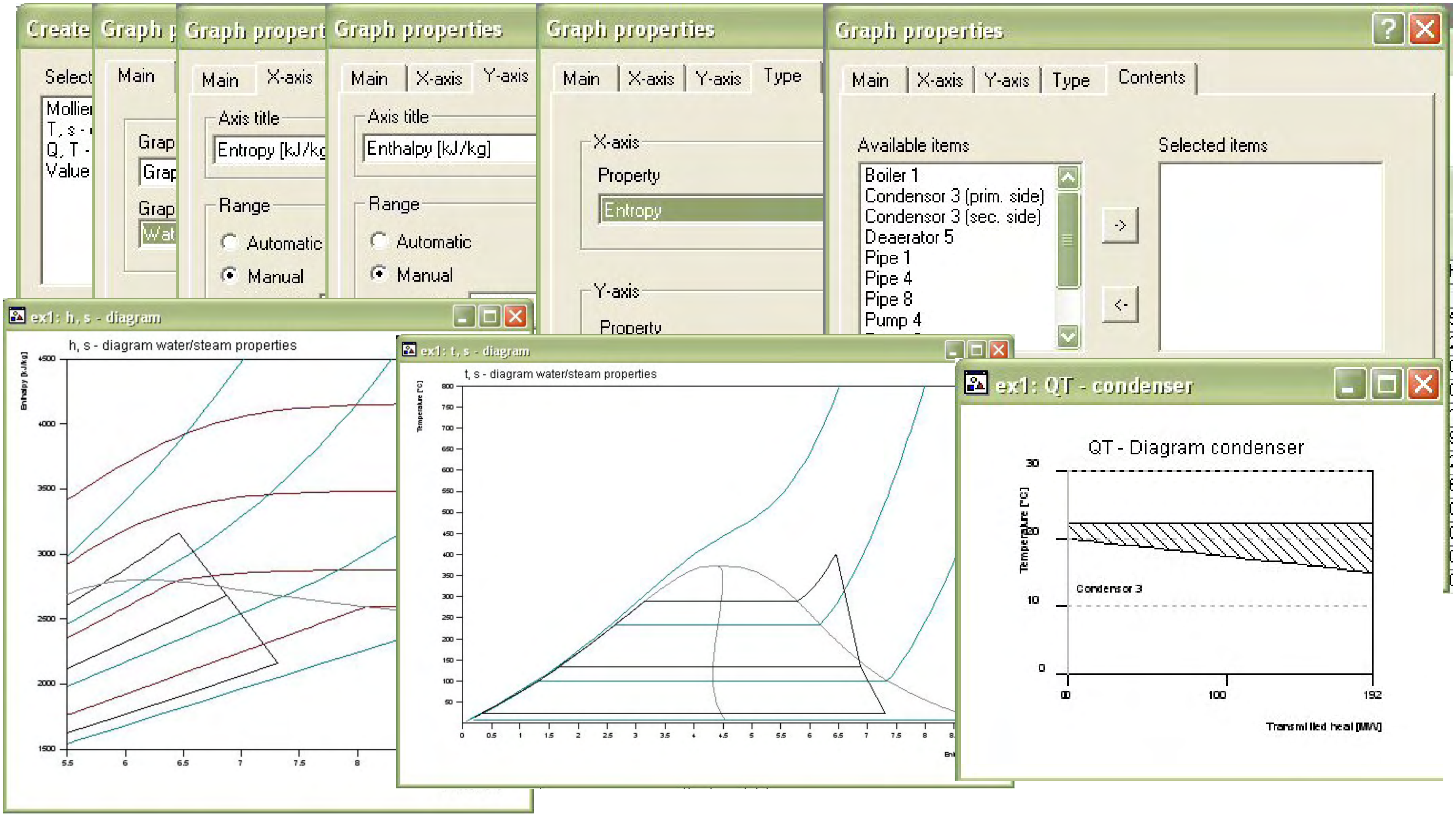
	No.	Apparatus	Type	Energy	Totals	Exergy	Totals
				[kW]	[kW]	[kW]	[kW]
Absorbed	1	Boiler	1	309406.19		322901.16	
power					309406.19		322901.16
Delivered	1	Generator	G	100000.00		100000.00	
gross power					100000.00		100000.00
Aux. power	4	Pump	8	69.36		69.36	
consumption	6	Pump	8	1315.14		1315.14	
	8	Pump	8	3874.27		3874.27	
					5258.78		5258.78
Delivered							
net power					94741.23		94741.23
Efficiencies	gross			32.320 %		30.969 %	
	net			30.620 %		29.341 %	

ex1: Energy balance

No.	Name	Type	Energy loss (enthalpy)	Energy loss (HHV)	Energy loss (LHV)
			[kW]	[kW]	[kW]
1	Boiler	1	-293935.88	-293935.88	-293935.88
2	Turbine	3	103092.78	103092.78	103092.78
3	Condensor	4	0.00	0.00	0.00
5	Deaerator	7	0.00	0.00	0.00
4	Pump	8	-61.86	-61.86	-61.86
6	Pump	8	-1249.75	-1249.75	-1249.75
8	Pump	8	-3692.14	-3692.14	-3692.14
7	Sink/Source	10	195846.84	195846.84	195846.84
1	Pipe		0.00	0.00	0.00
4	Pipe		0.00	0.00	0.00
8	Pipe		0.00	0.00	0.00
	Total:		0.00	0.00	0.00

WP#2 Evaluation of working fluids

CYCLE-TEMPO COMPUTER PROGRAM – Results in Diagram



NEXT – WP#2

Evaluation of working fluids:

Acquire REFPROP8 to study different working fluids

→ calculate CYCLE-TEMPO results for LOWBIN prototypes conditions with REFPROP8 working fluids

→ choose the best working fluids for each LOWBIN prototypes

Technology assessment of heat exchangers

- Research of most used heat exchangers types for this kind of applications
- Research and acquisition of a program to design the heat exchanger, aiming the lowest temperature operation threshold

NEXT – WP#3

Pre-prototype development and laboratory measurements

Application of the information obtain in the previous WP

- **specifying working fluids and heat exchangers**
- **optimizing the heat exchanger**

Utilization of Cycle-Tempo

- **study modifications in the cycle (components; temperatures variations…), to optimize the pre-prototype**

Environmental impacts study

NEXT – WP#5

Monitoring and analysing geothermal energy parameters, ...

Continuing the calculations with the model

→ **To help to define the most important measurement points**

Evaluation and analysis of monitored parameters

Evaluation of Cycle-Tempo performance

Technology validation report

WP#6

Presentations in conferences and papers in scientific journals

Submission of scientific articles with the achieved results

Partners suggestions…
For example for apparatus input data for LOWBIN prototypes, such as temperatures of cold and hot sources…

thank you for your attention

σας ευχαριστώ

grazie

dankeschön

dankchen

mulţumesc

obrigada

merci

takk fyrir